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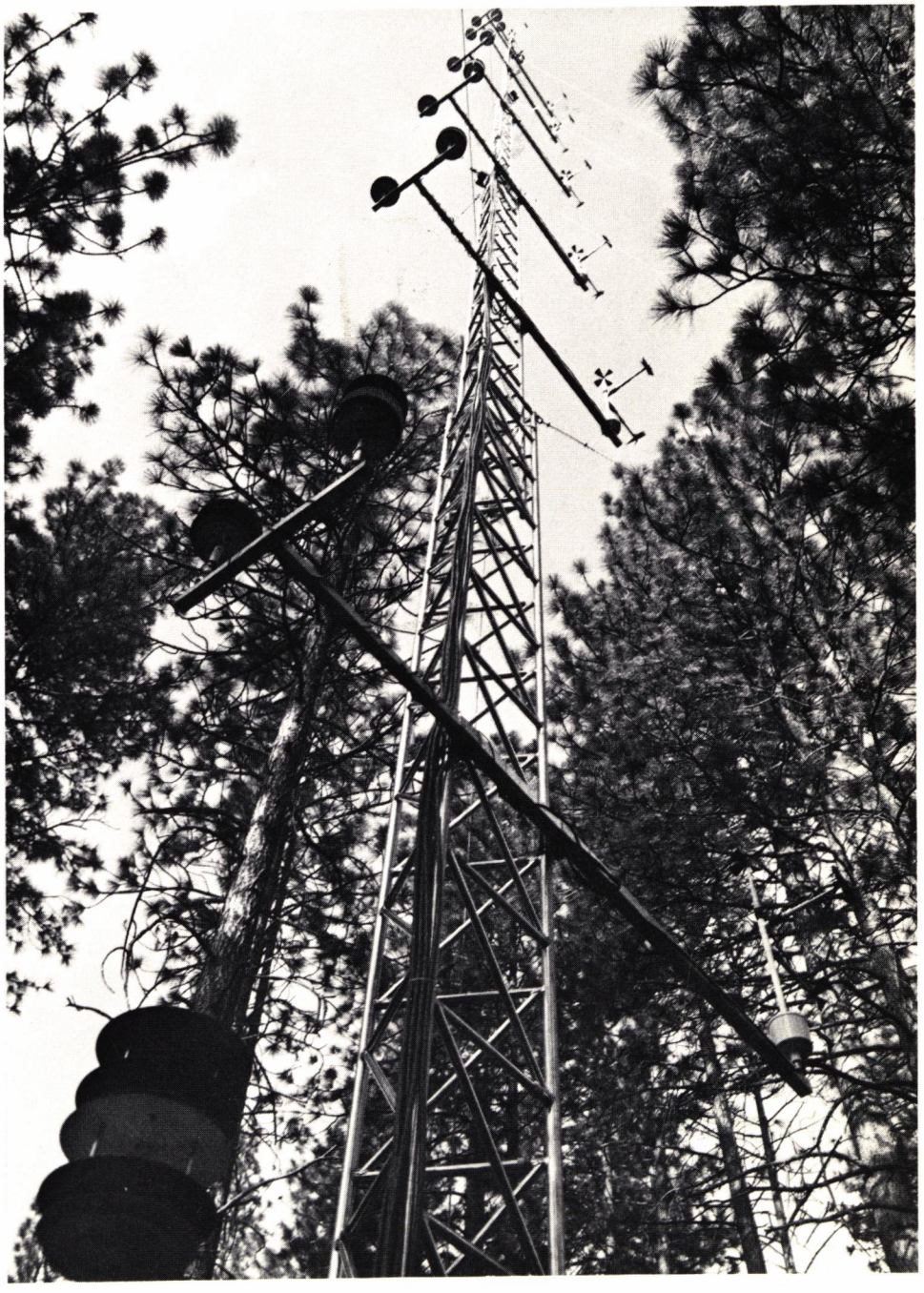
SUPPLEMENT TO - Preliminary Canopy Structure Estimates For The Forest Site of The Program WIND Study

United States
Department of
Agriculture

Forest Service

**Forest Pest
Management**

Davis, CA.



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USDA Forest Service (J. Barry) photograph of 32 meter tower located at the Program WIND forest study site on Diamond Lands Corporation land near Lyman Springs, CA, 1986.

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PREFACE

Program WIND is a cooperative applied research program conducted by the USDA Forest Service, the U.S. Army and cooperators. The objective of Program WIND is to evaluate computer-based predictive meteorological and dispersion models.

Program WIND field studies began in the summer of 1985 and ended the fall of 1987. Meteorological measurements were taken and related studies were conducted in an area approximately 80 km x 80 km on private lands in Northern California

Data reported herein were collected during the summer of 1985 at the forest site described by Klein and Boom (1987). Questions and comments are invited and should be directed to John W. Barry, Program Manager, Davis, CA, (916) 758-4600.

FPM 88-1
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SUPPLEMENT TO- Preliminary Canopy Structure Estimates for the Forest Site of the Program WIND Study

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Introduction:

This memorandum supplements the Program WIND report "Preliminary canopy structure estimates for the forest site of the Program WIND Study" - FPM-USDA-86-3 (Bergen 1986).

Methods of measurement and data analysis are described in that report.

Figure 1, a schematic of the tower arrangement at the Atmospheric Science Laboratory forest site is taken from page 18 of the report "Program WIND: Phase II and III Operations Plan, December 1985."* The test site is about 70 km east of Red Bluff, California, at an altitude of approximately 400 m, the stand consists mainly of ponderosa pine (Pinus ponderosa), (Klein and Boom 1987).

Measurements:

Experience with the first two plots described in the prior report indicated that tape measurements of horizontal distances on the plot added little to the accuracy of the tree height determinations, but considerably to the time required for the survey. In the present study, distances were paced off. Comparison with tape measurements showed only about a 10 percent error with no particular bias. The consequent decrease in sampling time allowed the sampling plots to be expanded from 25 m by 25 m to 50 m by 50 m. The plots were centered on the nearby tower.

Heights were measured with an Abney level as in the preceding surveys. Procedure in regard to the canopy photographs was unchanged.

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*Internal document Project WIND

Two surveys were taken as before--a complete census of live stems in the plot with regard to species and diameter at breast height (DBH; breast height is nominally 1.5 m), and, separately, a sampling of the joint distribution of DBH, height to the live crown (HLC), total height (HT), and species. This last survey was usually limited by visibility to about 20 stems.

Results for the complete census are shown in tables 1a, 1b, and 1c. Results for the height survey are shown in tables 2a, 2b, and 2c.

Because the longer crowns are more easily distinguished from the general canopy background, they are overrepresented in the sample used to calculate height variations. This was not a problem with Plot 1 where the average DBH's were essentially the same; it poses problems for Plot FC-2 where the height sample survey shows $\overline{DBH}$ at 32 cm as compared to 21 cm for the total census. The standard deviations were both 13 cm. Such a bias is also evident for Plot 2. Some correction might be made by reweighting the stem data used in constructing the vertical foliage distribution profiles or by a formal regression of HT and HLC on DBH.

Preliminary Analysis:

1. Leaf Area Index (LAI). No new information has come to light on structural relations for incense cedar (Libocedrus decurrens) since the original report was issued. In the present calculations, as before, it was considered equivalent to the ponderosa pine. The same relations were used, including those for the oak (Quercus kelloggi) as before, to calculate the LAI, as noted for each plot on the tables (1a, 1b, and 1c), from the DBH and species survey.

2. Canopy Cover. The canopy cover within 30 degrees of the zenith was calculated from the photographs, given as figures 2a, 2b, and 2c, using a

gridded overlay as before. These results are noted on tables (1a, 1b, and 1c) as the average of the four photographs and their range.

3. Vertical Foliage Area Distribution. The vertical distribution of foliage area was calculated from the data of tables (2a, 2b, and 2c) for each plot using the methodology of the prior report; i.e., the summation of truncated Gaussian crowns. The results are shown in tables (3a, 3b, and 3c) and in figures (3a, 3b, and 3c) in terms of the fraction of the total LAI, $\frac{\text{LAI}}{\text{LAI}}$ in the 50 cm layer centered at the listed height Z and the fraction of the $\frac{\text{LAI}}{\text{LAI}}$ total LAI below that level (ACC). The average tree height ($\overline{\text{HT}}$) and the height above 85 percent of the foliage area (Z85) are also indicated on the figures.

General Comments:

Table 4 recapitulates some of the parameters measured for all of the five plots. The canopy cover for Plots 1 and 2 have been recomputed using a more detailed template. The easterly decrease of LAI noted between Plots 1 and 2 seem to be sustained between Plots 2 and 3. There is also some indication of a north to south decrease between FC-2 and FC-1. The corresponding trends in $\overline{\text{DBH}}$ are consistent qualitatively. The slight decrease between Plot 2 and Plot 3 as compared with the LAI difference reflects the relatively high skew of the $\overline{\text{DBH}}$ distribution on Plot 3. More than 85 percent of the DBH values fall below $\overline{\text{DBH}}$.

The average canopy cover $\overline{C}$ appears to vary somewhat more consistently with the LAI values for the last three plots than is the case between Plots 1 and 2. It seems that a higher sampling density would be needed to establish any reasonable correlation.

The interplot variations of $\overline{\text{HT}}$, Z85, and HMX, (the height of maximum foliage density), do not appear to be significant in view of the approximations involved.

The term "Leaf Area Index" abbreviated LAI in the initial report and this supplement refers to half the total estimated foliage surface area above each projected unit area of the stand floor. The vertically projected foliage area per unit area of stand floor, more commonly used in defining LAI, cannot be calculated without some assumption concerning the leaf or needle orientation.

REFERENCES

Bergen, J. D. 1986. Preliminary canopy structure estimates for the forest site of the Program WIND study. FPM 86-3. Davis, CA: Forest Pest Management, Forest Service, U.S. Department of Agriculture; 22 p.

Klein, B. and Boom, Bruce. 1987. Forest site characterization. FPM 87-2, Forest Pest Management, Forest Service, U.S. Department of Agriculture; 15p.

Table 1a. Total census of stems (DBH-species), Plot 3

DBH cm		DBH cm		DBH cm	
16.1	1	8.5	2	18.6	1
9.7	1	19.8	1	19.8	1
27.5	2	10.5	1	12.0	1
29.1	2	12.5	1	34.4	2
10.0	2	13.6	1	10.5	2
17.8	1	40.9	1	28.3	1
18.6	1	30.7	1	12.1	2
13.4	1	9.7	1	12.9	2
13.4	1	10.1	1	11.7	1
27.5	1	9.1	1	34.0	1
31.1	1	7.3	1	12.9	1
29.1	1	10.9	1	15.4	2
21.0	1	7.9	1	15.6	2
12.1	1	15.4	1	18.6	2
31.6	1	25.5	1	10.5	2
30.7	1	8.9	1	7.7	2
21.4	2	17.0	1	10.9	1
17.8	1	25.9	1	12.9	1
15.0	1	13.8	1	12.1	1
22.6	1	23.5	1	17.8	1
32.0	1	15.8	1	27.5	1

Table 1a (continued)

DBH cm		DBH cm		DBH cm	
14.6	1	26.9	1	17.4	1
26.7	1	11.2	1	28.3	1
21.8	1	12.1	1	23.9	1
21.4	1	12.1	1	17.4	1
9.7	2	8.5	1	34.0	1
13.8	1	20.2	1	27.9	1
16.6	1	8.9	1	37.2	1
22.7	1	12.1	1	13.4	1
12.5	1	23.9	1	29.9	1
10.1	1	11.3	1	29.5	1
25.1	1	9.7	1	17.4	1
24.3	1	12.5	1	19.4	1
16.2	1	13.8	1	19.4	1
14.8	1	18.6	1	26.7	1
19.4	1	25.1	1	21.8	1
21.0	1	20.2	1	10.5	1
20.6	1	20.2	1	16.0	1
22.2	1	14.2	1	23.5	1
15.4	1	10.1	1	17.0	1
18.2	1	8.1	1	21.8	1
25.1	1	25.1	1	10.9	2

Table 1a (continued)

DBH cm		DBH cm		DBH cm	
12.5	1	31.6	1	8.5	2
11.3	1	16.1	1	19.8	1
19.0	1	17.8	1	11.7	1
23.1	1	8.9	1	31.5	1
15.0	1	14.2	1	8.9	1
26.7	1	17.8	1	15.4	1
6.1	1	9.7	1	11.7	1
12.0	1	11.3	1	20.2	1
27.9	1	8.5	1	12.9	1
24.3	1	15.0	1	9.3	1
12.1	1	14.2	1	32.4	1
9.7	1	16.2	1	15.4	2
20.5	1	19.4	1	10.9	1
13.8	1	21.0	1	17.4	1
25.9	1	10.9	1	10.5	1
10.5	1	9.5	1	17.8	1
10.5	1	25.1	2	17.0	1
22.7	1	17.8	1	10.5	1
26.7	1	9.3	1	8.5	1
7.9	1	5.1	1	8.5	1

Table 1a (continued)

DBH cm		DBH cm		DBH cm	
13.3	1	8.1	1	10.8	1
19.0	1	25.5	1	11.3	1
29.5	1	16.6	1	16.6	1
9.3	1	28.7	1	19.8	1
15.4	1	14.6	1	18.6	1
15.8	1	10.5	1	19.4	1
11.3	1	20.6	1	16.0	1
17.4	1				

Species: pine =1, cedar = 2, oak = 3

Number of live stems = 210

Average DBH = 17.5 cm

Standard deviation of DBH = 7.2 cm

Leaf Area Index = 2.5

Canopy cover = .28

Range of canopy cover = .43

Table 1b. Total census of stems (DBH-species), Plot FC-1

DBH cm		DBH cm		DBH cm	
14.6	3	20.2	1	28.7	1
61.9	1	13.8	1	24.7	1
15.6	1	22.6	1	13.3	1
19.4	1	19.8	1	39.5	1
19.4	1	25.1	1	43.3	1
14.6	1	40.9	1	46.5	1
24.3	1	26.3	1	42.1	1
25.1	1	48.9	1	35.6	1
20.9	1	29.0	1	50.2	1
21.7	1	22.7	1	42.9	1
24.7	1	19.4	1	30.7	1
20.2	1	22.7	1	45.1	1
28.3	1	42.5	1	38.8	1
16.6	1	7.5	1	40.0	1
29.1	1	30.3	1	34.6	1
26.3	1	38.0	1	30.7	1
25.1	1	32.8	1	42.1	1
31.5	1	30.2	1	34.6	1
24.7	1	31.0	1	23.3	1
23.5	1	20.2	1	30.7	1
54.2	1	38.8	1	28.3	1

Table 1b (continued)

DBH cm		DBH cm		DBH cm	
37.0	1	41.7	1	18.2	1
42.1	1	22.2	1	27.9	1
44.9	1	36.6	1	55.0	1
48.7	1	34.4	1		
59.1	1	16.4	1		

Species: pine = 1, cedar = 2, oak = 3

Number of live stems = 77

Average DBH = 31.2 cm

Standard Deviation of DBH = 11.8 cm

Leaf Area Index = 2.7

Canopy Cover = .55

Range of canopy cover = .47

Table 1c. Total census of stems (DBH-species), Plot FC-2

DBH cm		DBH cm		DBH cm	
42.9	1	11.3	1	25.1	1
11.3	1	27.3	1	8.7	2
35.8	1	26.3	1	8.1	1
27.3	2	30.3	1	8.1	1
26.9	1	12.1	2	13.8	2
45.1	1	23.9	1	34.0	1
23.5	1	10.4	1	33.6	1
44.9	1	25.7	1	11.7	2
35.6	1	25.1	1	11.7	1
41.7	1	22.7	1	46.1	1
33.2	1	9.3	1	40.9	1
24.3	1	43.7	1	17.0	1
38.01	1	12.1	1	11.7	2
10.8	1	14.2	1	14.2	1
10.9	2	36.0	1	12.8	2
8.3	2	46.9	1	20.6	2
25.1	1	10.1	2	25.9	1
8.1	2	10.1	1	17.6	2
39.6	1	11.3	2	24.7	2
6.5	2	16.2	2	25.7	1
32.2	2	38.8	1	21.4	1

Table 1c (continued)

DBH cm		DBH cm		DBH cm	
32.4	2	17.0	1	49.6	1
40.9	1	31.1	1	16.8	1
10.9	1	12.4	1	18.6	1
8.3	2	11.3	1	22.5	1
12.1	1	11.3	2	20.5	1
14.6	2	36.4	1	12.1	2
12.5	1	51.0	1	21.7	1
8.3	1	40.0	2	10.5	2
11.3	1	27.5	2	13.8	1
20.2	1	24.7	1	13.4	1
24.7	2	10.1	2	9.3	1
36.4	2	27.1	1	7.7	1
9.7	2	37.1	1	10.5	1
10.9	1	10.9	2	27.9	1
9.6	2	10.1	2	11.3	2
10.9	2	31.1	1	16.2	1
34.2	1	14.6	2	6.7	2
8.1	1	20.2	1	22.3	1
10.0	1	34.0	1	6.5	2
22.7	1	16.2	2	9.3	2
10.1	1	17.4	1	69.2	1

Table 1c (continued)

DBH cm		DBH cm		DBH cm	
10.8	2	10.5	1	13.8	1
33.2	1	14.6	1	12.5	2
12.9	2	17.0	2	15.0	1
24.7	1	7.5	2	13.8	2
15.0	1	8.5	2	9.7	2
44.7	1	19.8	1	23.5	1
29.8	2	15.4	1	9.3	2
19.3	1	12.5	2	37.2	1
20.6	1	10.1	2	15.6	1
13.4	1	15.0	2	36.4	1
13.4	2	28.7	1	10.9	2
42.3	1	29.9	1	23.3	1
19.7	1	20.6	2	15.0	2
21.0	1	13.4	2	27.1	2
14.6	1	12.8	2	9.7	1
15.6	1	43.3	1	9.3	1
10.5	2	22.6	1	18.6	2
27.5	1	12.9	2	25.1	2
34.0	1	28.3	1	8.9	1
29.9	1	8.3	2	30.3	1
9.1	2	12.8	2		

Table 1c (continued)

DBH cm		DBH cm	
34.8	1	6.9	2
12.5	1	8.1	2
18.6	1	20.2	1
10.8	1	11.7	2
14.8	1	27.5	1
20.6	2	10.5	2

Species: pine = 1, cedar = 2, oak = 3

Number of live stems = 200

Average DBH = 20.5 cm

Standard deviation of DBH = 11.5 cm

Leaf Area Index = 3.6

Canopy cover = 0.69

Range of canopy cover = 0.20

Table 2a. Detailed sample survey of Plot 3

Height (cm)	HLC (cm)	DBH (cm)	Species
1776	715	34.0	1
2029	714	41.7	1
1691	770	25.7	1
1011	492	18.4	2
1233	536	20.6	1
1138	523	19.4	1
1466	620	26.1	1
1249	487	21.8	1
807	215	18.2	2
620	254	12.1	1
1055	389	20.2	1
897	646	14.0	1
1011	519	16.2	1
1544	929	22.5	1
1394	820	21.0	1

Table 2a. (continued)

Height (cm)	HLC (cm)	DBH (cm)	Species
1375	746	15.4	1
2170	1043	40.9	1
1689	766	32.8	1
854	205	13.8	1
777	407	12.9	2

Species: pine = 1, cedar = 2, oak = 3

Average height = 12.9 m

Standard deviation of height = 4.2 m

Average DBH = 22.4 cm

Standard deviation of DBH = 8.5 cm

Table 2b. Detailed sample survey of Plot FC-1

Height (cm)	HLC (cm)	DBH (cm)	Species
918	512	12.1	1
1556	1068	34.2	1
1751	1068	26.3	1
854	615	19.8	1
1273	735	26.7	1
1865	1025	38.4	1
1614	1076	41.7	1
1650	1041	43.7	1
1264	734	25.5	1
1494	930	31.1	1
1823	837	33.6	1
1315	598	26.1	1
1823	777	37.1	1
1960	945	40.5	1
2031	991	31.4	1
1590	811	36.0	1
1558	779	27.9	1
1720	811	35.2	1
2668	977	66.3	1
1799	955	28.6	1

Table 2b (continued)

Species: pine = 1, cedar = 2, oak = 3

Average height = 15.0 m

Standard deviation of height = 3.9 m

Average DBH = 33.1 cm

Standard deviation of DBH = 10.6 cm

Table 2c. Detailed sample survey, Plot FC-2

Height (cm)	HLC (cm)	DBH (cm)	Species
1037	789	28.1	1
1686	1076	19.4	1
2642	1191	46.9	1
2203	1050	37.2	1
2409	1297	31.1	1
2009	902	30.7	1
2289	922	40.1	1
2186	1366	35.6	1
1776	1230	25.1	1
2114	1268	29.0	1
2265	1155	45.7	1
2436	1906	27.1	1
683	260	14.2	2
803	325	12.4	2
1076	269	29.9	2
2613	892	53.4	1
1166	799	15.4	1
2179	1127	12.1	2
2938	1366	62.3	1
1749	902	33.2	1
1945	986	39.6	1

Table 2c (continued)

Height (cm)	HLC (cm)	DBH (cm)	Species
1783	922	33.6	1
1766	1127	32.2	1

Average height = 19.0 m

Standard deviation of height = 5.9 m

Average DBH = 31.9 cm

Standard deviation of DBH = 12.5 cm

Table 3a. Estimated vertical distribution of fractional leaf area, Plot 3

Height (cm)	$\frac{\Delta LAI}{LAI}$	ACC
50	0	0
100	0	0
150	0	0
200	0	0
250	0	0
300	0	0
350	.002	.002
400	.005	.007
450	.008	.015
500	.010	.025
550	.011	.035
600	.011	.047
650	.013	.060
700	.019	.079
750	.028	.107
800	.031	.137
850	.029	.166
900	.028	.193
950	.090	.222
1000	.034	.257

Table 3a. (continued)

Height (cm)	$\frac{\Delta LAI}{LAI}$	ACC
1050	.044	.300
1100	.054	.354
1150	.063	.418
1200	.069	.487
1250	.071	.558
1300	.067	.625
1350	.060	.685
1400	.053	.738
1450	.047	.785
1500	.042	.828
1550	.039	.866
1600	.034	.900
1650	.029	.930
1700	.024	.954
1750	.018	.971
1800	.012	.984
1850	.008	.991

Table 3a. (continued)

Height (cm)	$\frac{\Delta LAI}{LAI}$	ACC
1900	.005	.996
1950	.003	.998
2000	.001	.999
2050	.001	1.000
2100	.000	1.000

Table 3b. Estimated vertical distribution of fractional leaf area, Plot FC-1

Height (cm)	$\frac{\Delta LAI}{LAI}$	ACC
50		
100		
150		
200		
250		
300		
350		
400		
450		
500		
550		
600		
650	.001	.001
700	.003	.004
750	.004	.008
800	.003	.010
850	.004	.014
900	.009	.023
950	.014	.037
1000	.019	.056

Table 3b. (continued)

Height (cm)	$\frac{\Delta LAI}{LAI}$	ACC
1050	.023	.079
1100	.028	.108
1150	.038	.146
1200	.053	.199
1250	.070	.268
1300	.084	.352
1350	.089	.441
1400	.081	.522
1450	.067	.589
1500	.054	.644
1550	.044	.688
1600	.037	.724
1650	.032	.757
1700	.030	.787
1750	.029	.815
1800	.029	.843
1850	.027	.870
1900	.025	.895
1950	.023	.918
2000	.020	.938
2050	.017	.954
2100	.013	.968
2150	.010	.978

Table 3b. (continued)

Height (cm)	$\frac{\Delta LAI}{LAI}$	ACC
2200	.008	.986
2250	.005	.991
2300	.004	.995
2350	.002	.997
2400	.001	.998
2450	.001	.999
2500	.001	1.000

Table 3c. Estimated vertical distribution of fractional leaf area, Plot FC-2

Height (cm)	$\frac{\Delta LAI}{LAI}$	ACC
50	.000	.000
100	.000	.000
150	.000	.000
200	.000	.000
250	.000	.000
300	.000	.000
350	.000	.000
400	.001	.001
450	.002	.003
500	.003	.006
550	.004	.010
600	.004	.014
650	.005	.018
700	.004	.023
750	.004	.026
800	.002	.029
850	.002	.031
900	.005	.035
950	.004	.039
1000	.002	.041

Table 3c. (Continued)

Height (cm)	$\frac{\Delta LAI}{LAI}$	ACC
1050	.002	.043
1100	.003	.045
1150	.006	.051
1200	.010	.061
1250	.017	.078
1300	.025	.103
1350	.033	.135
1400	.0411	.177
1450	.047	.224
1500	.050	.274
1550	.052	.326
1600	.054	.380
1650	.056	.437
1700	.058	.495
1750	.059	.554
1800	.057	.610
1850	.052	.663
1900	.047	.710
1950	.042	.752
2000	.038	.790
2050	.035	.825

Table 3c. (Continued)

Height (cm)	$\frac{\Delta LAI}{LAI}$	ACC
2100	.033	.858
2150	.030	.888
2200	.027	.915
2250	.022	.937
2300	.017	.954
2350	.014	.968
2400	.010	.978
2450	.007	.986
2500	.005	.991
2550	.004	.995
2600	.002	.997
2650	.001	.998
2700	.001	.999
2750	.001	1.000
2800	.000	

Table 4.

Plot	1	2	3	FC-1	FC-2
LAI	8.4	4.0	2.5	2.7	3.6
DBH (cm)	34	21	18	31	21
Standard deviation of DBH (cm)	14	12	7	12	12
HT (m)	13	11	13	15	19
Standard deviation of HT	3.5	3	4	4	6
C	.53	.62	.28	.55	.69
Range of canopy Rc	.06	.12	.43	.47	.20
HMX (m)	10	10	13	13	18
Z85 (m)	14	13	16	18	21
HLC (m)	2	3	3	6	4
Sample DBH (cm)	34	35	22	33	32
Sample standard deviation of DBH (cm)	14	12	9	11	13

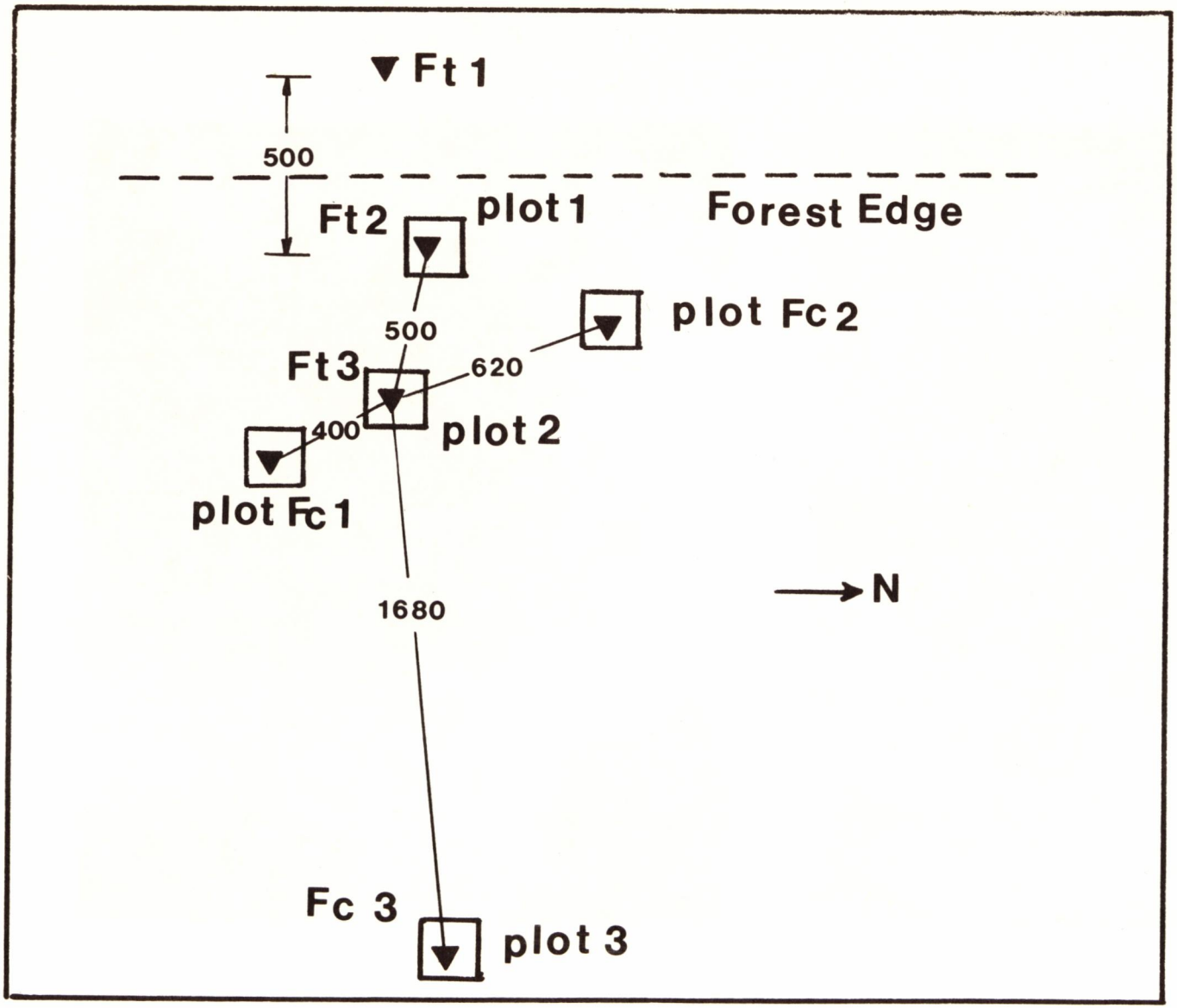

Figure 1. Locations of meteorological towers (noted as ▼) and survey plots. Distances in meters.

Figure 2a. Canopy photographs.
Plot 3: Maximum dimension 45^{o}.

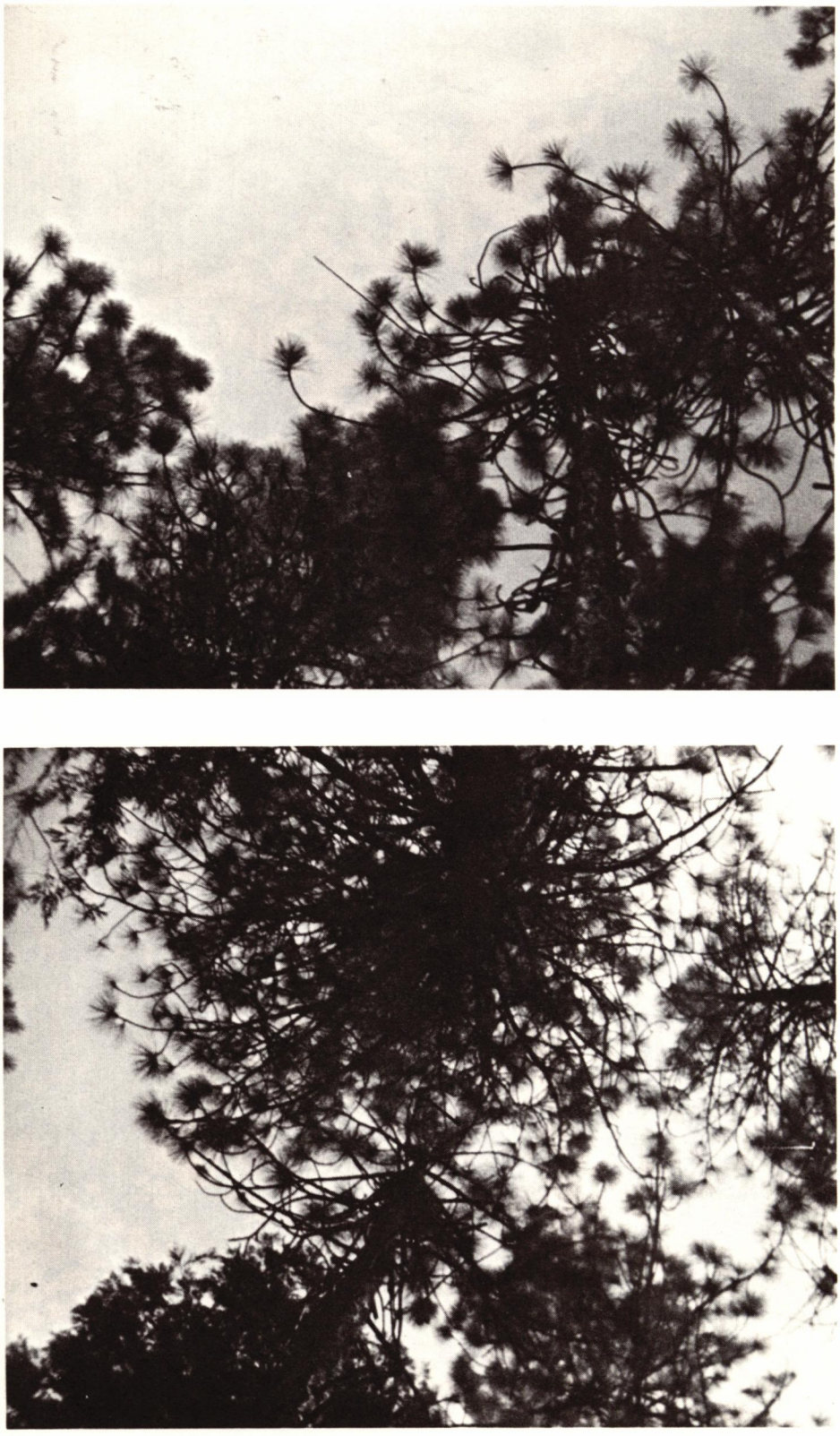

Figure 2a (cont.). Canopy photographs.
Plot 3: Maximum dimension 45°.

Figure 2b. Canopy photographs.
Plot FC-1: Maximum dimension 45^{o}.

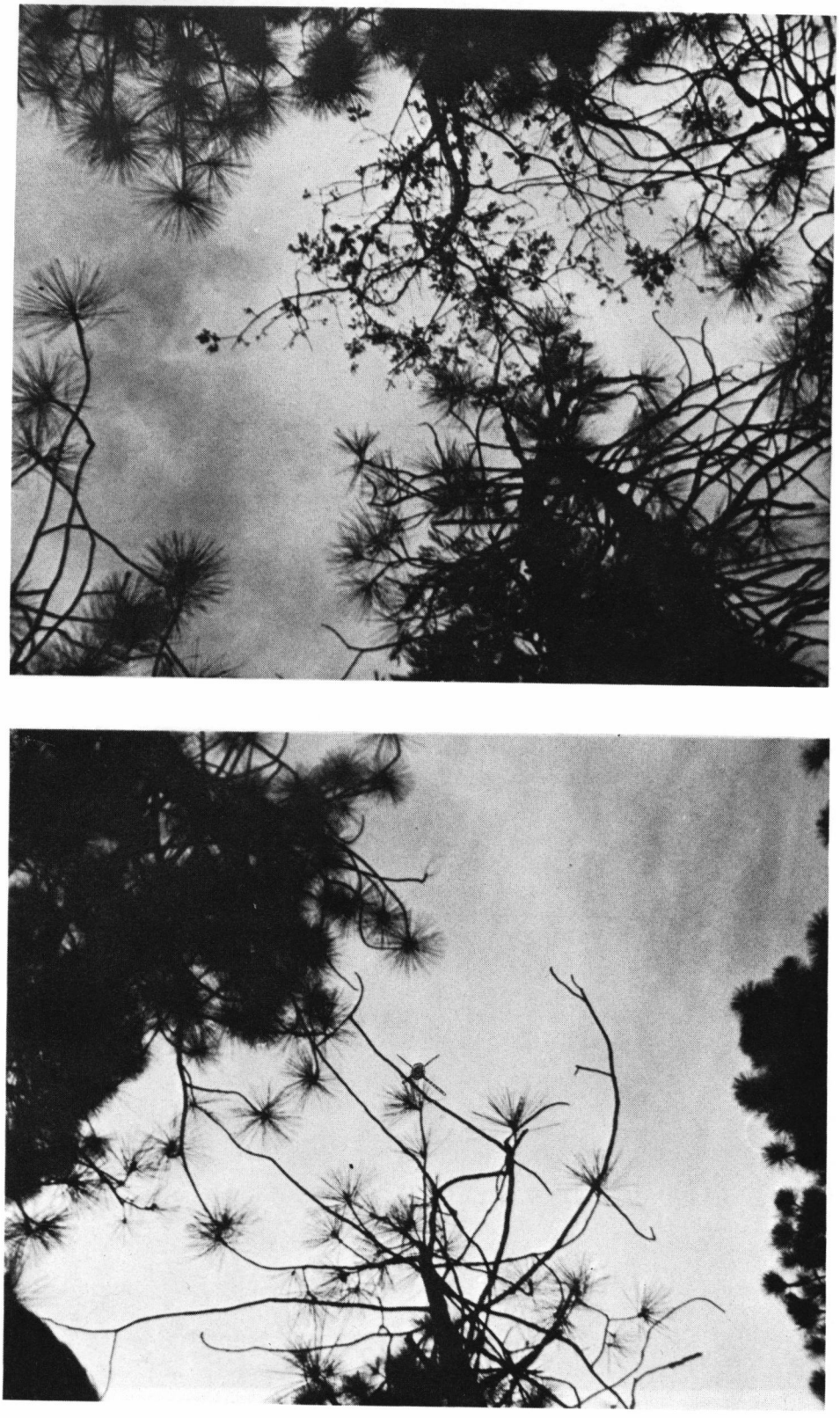

Figure 2b (cont.). Canopy photographs.
Plot FC-1: Maximum dimension 45^{o}.

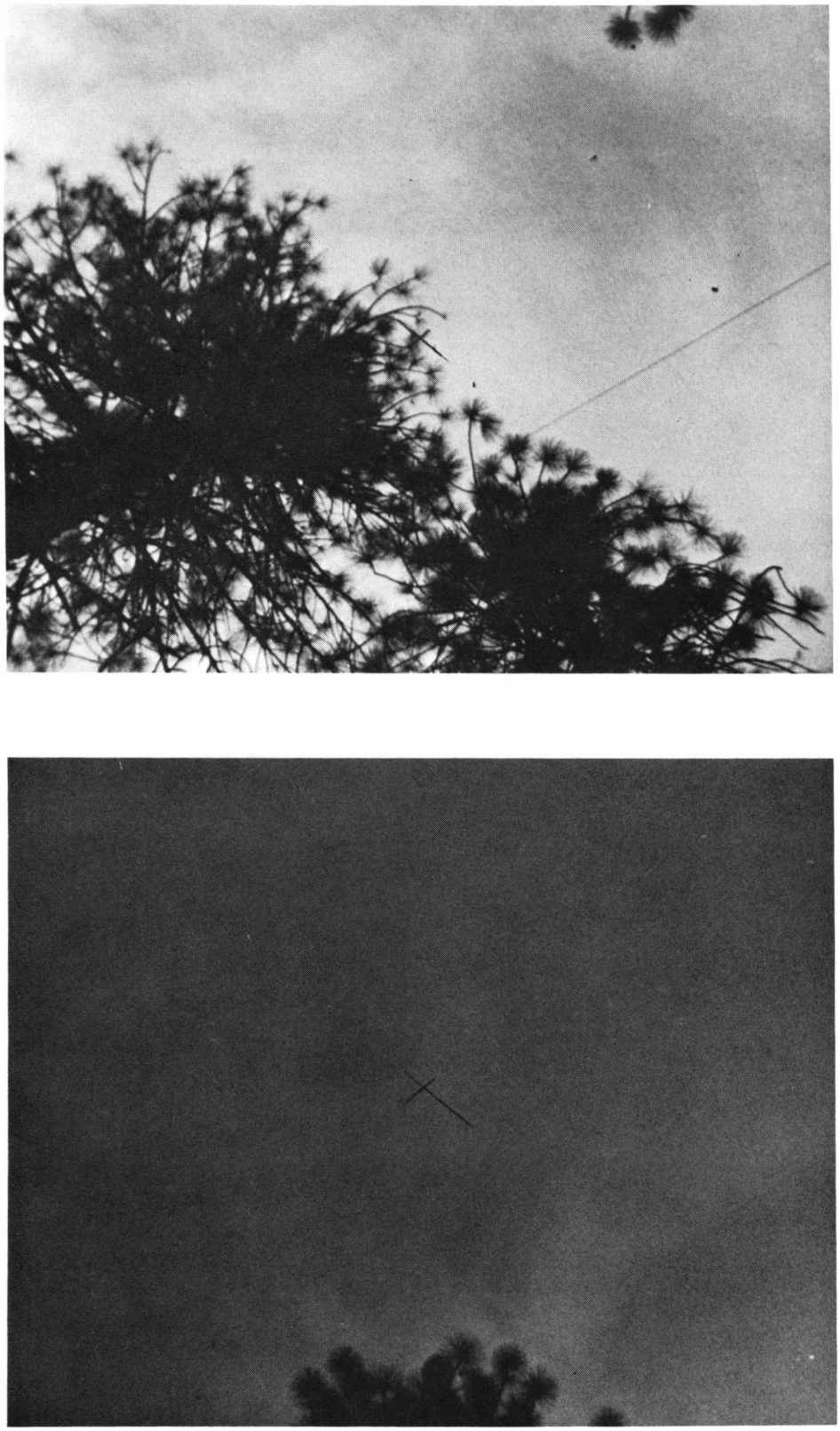

Figure 2c. Canopy photographs.
Plot FC-2: Maximum dimension 45^{o}.

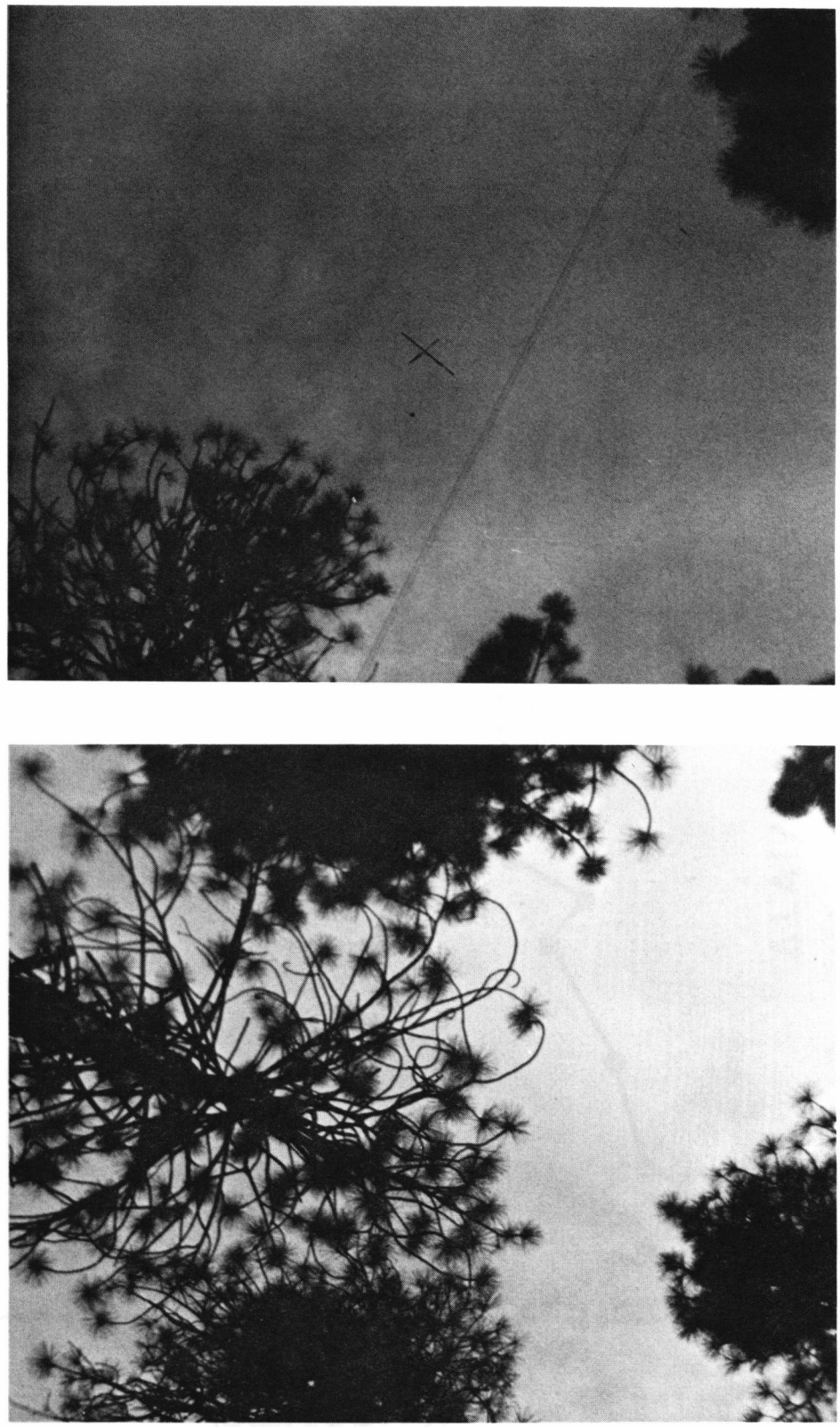

Figure 2c (cont.). Canopy photographs.
Plot FC-2: Maximum dimention 45^{o}.

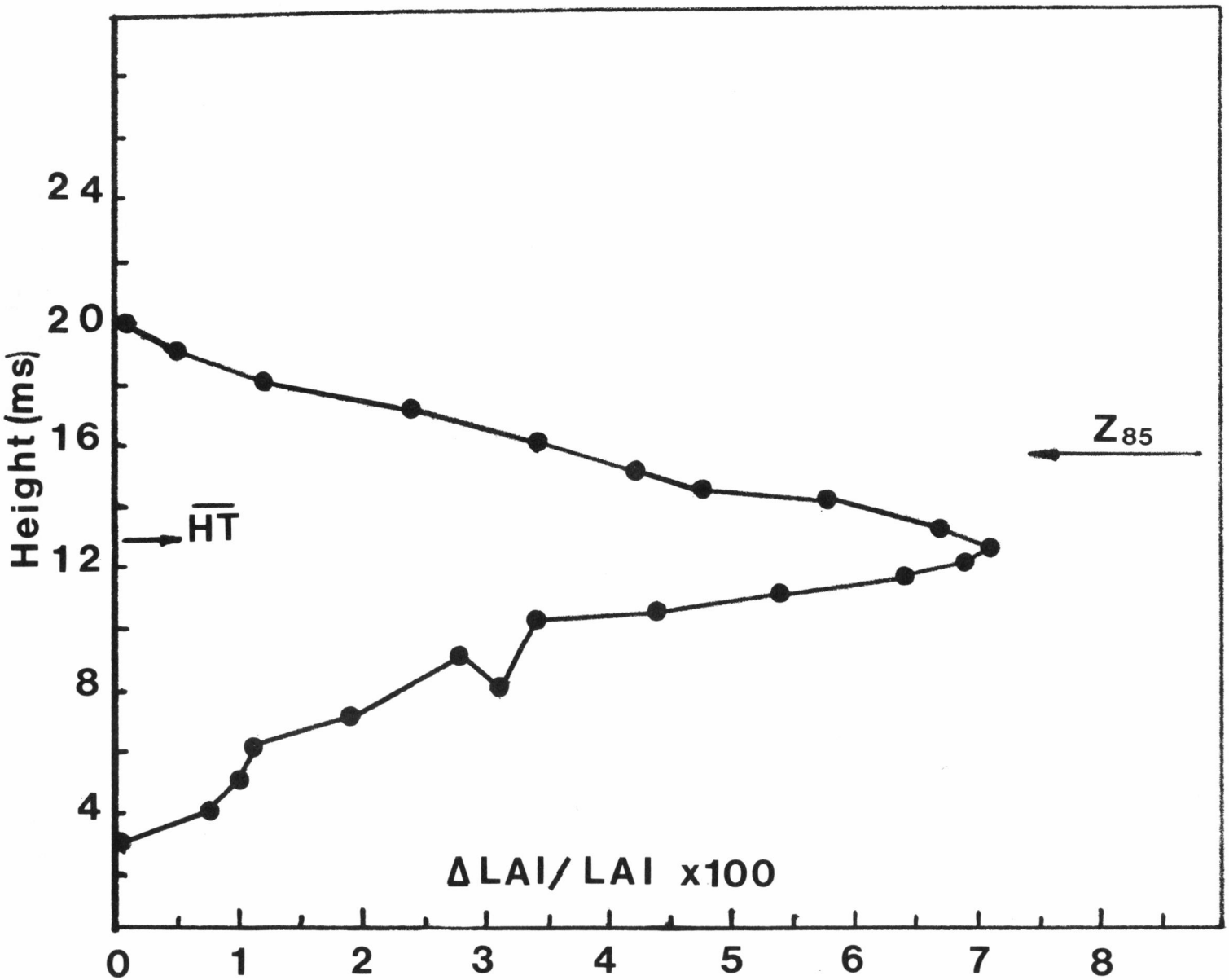

Figure 3a. Vertical distribution of foliage area for Plot 3.

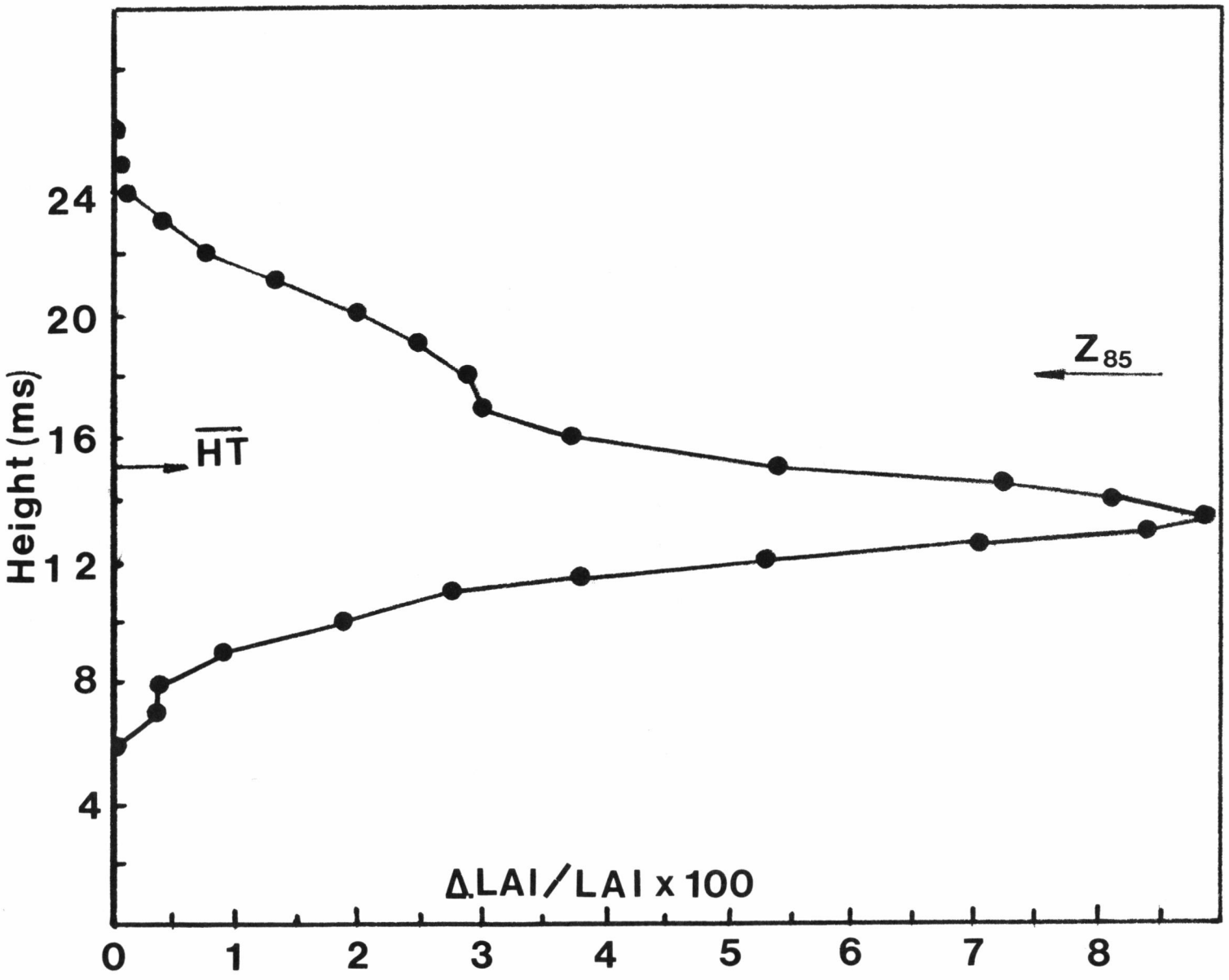

Figure 3b. Vertical distribution of foliage area for Plot FC-1.

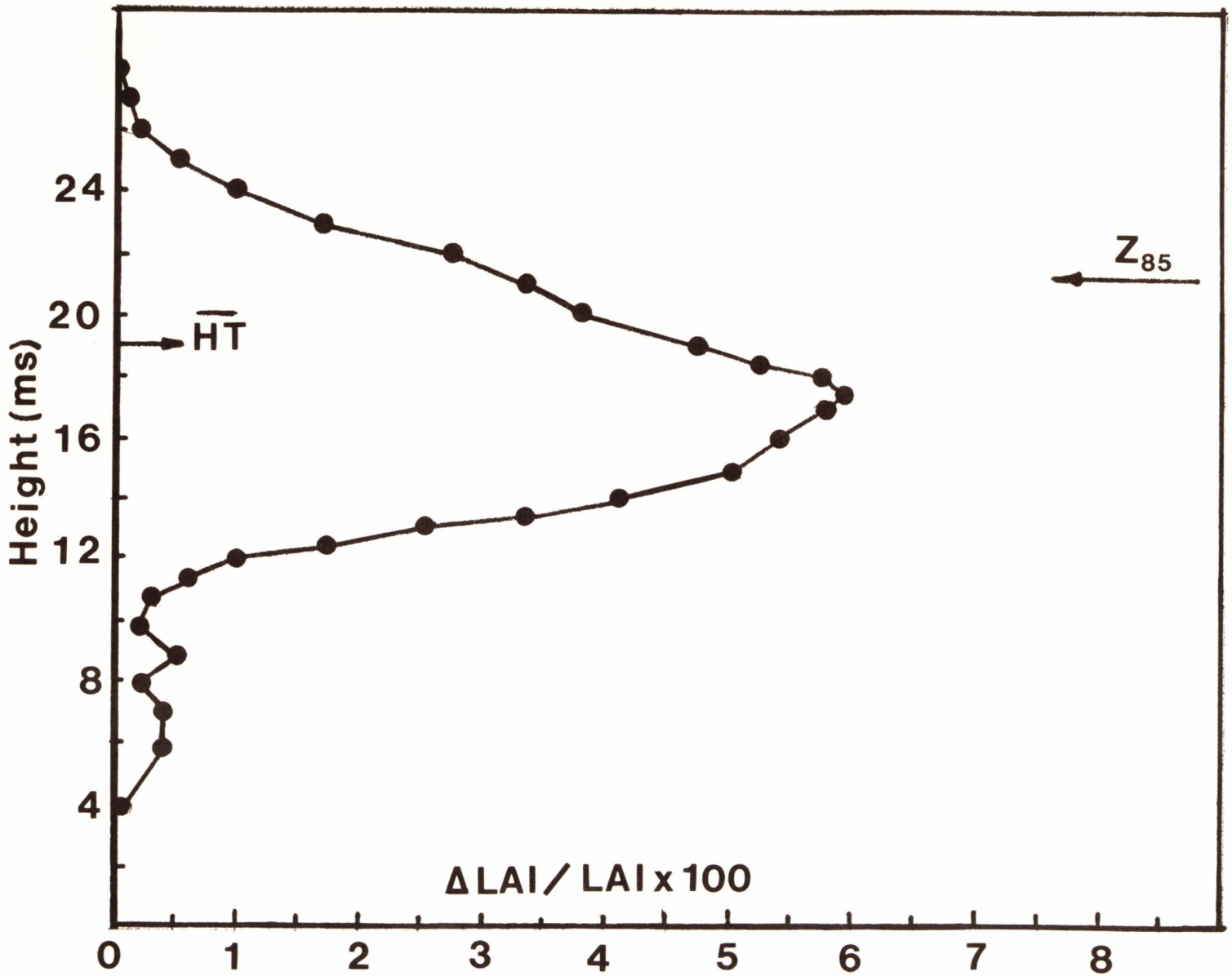

Figure 3c. Vertical distribution of foliage area for Plot FC-2.